COVID-19 has left healthcare systems around the world reeling — and pandemics are just one of the heightened threats humanity faces over the coming decades. How will we cope?

WORDS BY KATIE PUCKETT

The world spends a lot of money on healthcare.
But it's not enough.

1   **Between 1995 and 2016, global healthcare spending grew by 4% per year to reach US$8 trillion, 8.6% of the world economy.**[1]
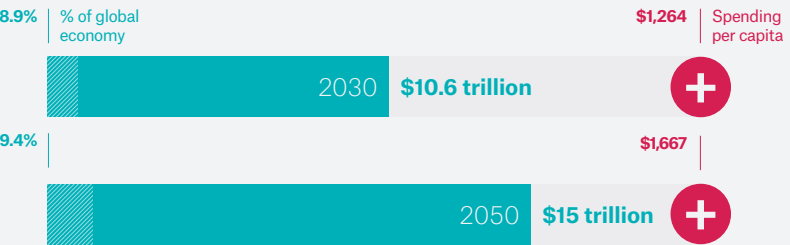This growth was driven by economic development and by governments prioritizing healthcare.

	% of global economy		Spending per capita
6.9%			$612
	1995	$3.5 trillion	➕
8.6%			$1,077
	2016	$8 trillion	➕

2   **This growth is expected to continue.**
Healthcare spending is projected to continue to grow by 1.8% annually.

	% of global economy		Spending per capita
8.9%			$1,264
	2030	$10.6 trillion	➕
9.4%			$1,667
	2050	$15 trillion	➕

It's not evenly distributed.

- In 2016, **41.7%** of total health spending was in the US
- The countries of sub-Saharan Africa collectively comprised **1%**
- High-income countries spent **US$5,252** per citizen
- Upper-middle-income countries spent **$491**
- Lower-middle-income countries spent **$81**
- Low-income countries spent just **$40**
- Low-income countries are home to **10%** of the global population, but only **0.4%** of global healthcare spending

The disparities will continue too …

- **69.4%** of this spending will be in countries currently considered high-income
- In 2050, low-income countries will comprise **15.7%** of the global population, but still only **0.6%** of spending on healthcare

But demand is increasing faster. That 4% annual increase in spending is just 2.7% per capita. The global population is increasing, and people are living longer. In 1950, average life expectancy at birth was 47. Today, it is 72. By 2050, it is projected to be 77, and by 2100, 82.[2]

A longer life doesn't necessarily mean a healthier one. Conditions that used to be fatal can now be cured, but survivors often have complex needs. The burden of non-fatal disease and injury is rising, and a greater number of people suffer from multiple chronic conditions. Between 1990 and 2017, the global burden of disability increased by 52%.[3]

With economic development and prosperity comes a greater incidence of non-communicable diseases such as diabetes, heart disease and cancer — not only in rich countries but in the emerging economies of South-east Asia, Africa and Latin America too. The prevalence of obesity has nearly tripled worldwide since 1975.[4] In 2017, non-communicable diseases caused 73% of deaths and 80% of disability worldwide.

Our expectations of healthcare are increasing too. Patients are starting to see themselves as consumers: they have instant access to information via their smartphones and wearables, and they don't understand why healthcare can't be like that too. There is growing pressure on providers to modernize and embrace new technologies.

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"Even in the wealthiest countries, we see health systems buckling under pressure. Health spending must be scaled up right away to meet urgent needs and the surge in demand"
António Guterres, United Nations

THE FUTURE OF HEALTHCARE

By 2050, there will be more than 1 billion people over 70.
Who's going to take care of us?

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"We do not have the capacity to meet growing demand. That means we have to do things very, very differently"

Suzanne MacCormick, WSP

As the century progresses, the global population will become progressively older. In 2010, there were 350 million people older than 70, and 11.8 people of working age for each of them. By 2030, the ratio of workers to over-70s will have tumbled to 7.9, and by the end of the century, it will be just 3.4.[5]

The healthcare workforce is larger than at any time in history. In OECD countries, employment in health and social work has grown by 42% since 2000, to encompass one in ten jobs.[6]
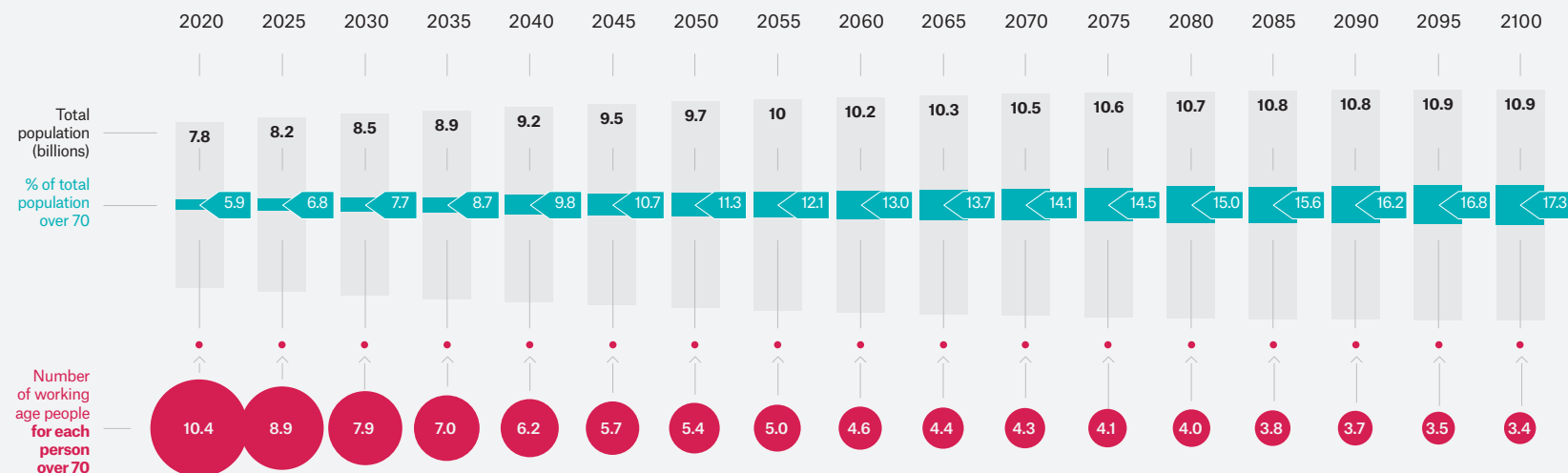
But there is still a shortage. Today only half of all countries have enough healthcare workers to deliver quality services, and no country is on track to meet all of the World Health Organization's health-related Sustainable Development Goals by 2030.[7] The ageing population and the rise in non-communicable diseases will generate demand for 40 million extra healthcare workers by 2030 — which would mean doubling the current workforce. Without action, the WHO warns that there will be a shortfall of 18 million healthcare workers, particularly in lower-income countries.[8]
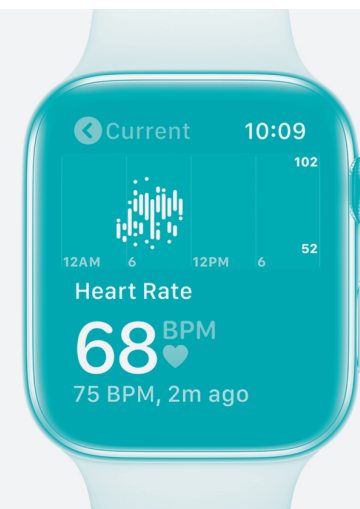
+ Healthcare workers of the future are more likely to come from Africa than anywhere else. Only Africa is projected to have an old-age dependency ratio in double figures by the middle of this century, with just under 16 workers to older people, compared to 3.5 in North America and just 2.7 in Europe.[9]

3 **Number of older people, 2020-2100** [10]
Proportion of total population

	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095	2100
Total population (billions)	7.8	8.2	8.5	8.9	9.2	9.5	9.7	10	10.2	10.3	10.5	10.6	10.7	10.8	10.8	10.9	10.9
% of total population over 70	5.9	6.8	7.7	8.7	9.8	10.7	11.3	12.1	13.0	13.7	14.1	14.5	15.0	15.6	16.2	16.8	17.3
Number of working age people for each person over 70	10.4	8.9	7.9	7.0	6.2	5.7	5.4	5.0	4.6	4.4	4.3	4.1	4.0	3.8	3.7	3.5	3.4

THE FUTURE OF HEALTHCARE

Can technology fill the gap?

The last decade has seen a resurgence in health R&D, particularly in medical technology. Healthcare is second only to IT in research, with worldwide R&D spending reaching US$177bn in 2019.

The last ten years have seen strong growth in patents too. In the world's top science and technology clusters, medtech is now the most frequent field of patenting. But this likely underestimates the actual level of innovation, notes the World Intellectual Property Organization, as health-related R&D is taking place in many other fields, including artificial intelligence.[11] Regulatory agencies such as the US Food and Drug Administration have approved record numbers of novel medical devices over the last five years, heralding an era of breakthroughs in material science, digital health and other technologies,[12] while venture capital is flooding into health start-ups.

New tools will diagnose problems, cure diseases, improve efficiency and disrupt business models. Genetics, stem cell research and 3D printing will enable more personalized treatments, while automation, data analytics and AI will underpin everything from robotic surgery and diagnosis-by-algorithm to caregiver support. Wearables will prevent illness by flagging risk factors and nudging us towards healthier lifestyles.

Healthcare is one of the biggest targets for the big four tech companies, with Alphabet, Apple, Amazon and Microsoft all investing heavily in R&D, acquisitions and collaborations. Google has shown that its AI can detect diseases such as lung or breast cancer and acute kidney injury earlier and with greater accuracy than traditional methods. In a study with more than 400,000 participants, researchers at Stanford University found the Apple Watch reliably identified heart rate irregularities that were confirmed to be atrial fibrillation, a leading cause of stroke and hospitalization.

"With new technology and service models, we're increasingly able to provide a lot of care outside hospital," says Mike Lovas, design director at Healthcare Human Factors in Toronto, a consultancy within Canada's largest

+ Smart thermometer company Kinsa has aggregated anonymized data from its network of devices and apps to create the US Health Weather Map, showing the level of flu-like symptoms — presumed to indicate COVID-19 — in different areas across the country.[13]

academic hospital network, UHN. "We're looking at how we can help people be healthy or enable them to manage their conditions at home, setting up systems to monitor and keep them stable."

In collaboration with cardiologist Dr Heather Ross, Lovas' team helped design Medly, an app that monitors patients at risk of heart failure, the single most common reason for hospital admissions in Canada. Every morning, patients check in with their weight, blood pressure and symptoms, and receive feedback from Medly's cloud-based algorithm — perhaps a warning about their salt intake or to increase their medication. If they need more attention, a nurse will be alerted. The system has not removed the need for human intervention, but it has changed the number and types of role. "Over time, we've made the system smarter and we've increased the patient-to-nurse ratio — we now have 400 patients to one registered nurse. We don't need a physician to field every clinical question."

Lovas is now design director of the Smart Cancer Care initiative at Princess Margaret Cancer Centre, one of the world's largest, which aims to reimagine the future of cancer care. Since the start of the COVID-19 pandemic, they have successfully virtualized around 75% of clinic visits. "We're now exploring how we can deepen virtual care, so that it's not just phone or video. We're looking at nurse-led virtual clinics, asynchronous messaging, remote symptom tracking, and automated follow-up visits — the patient submits lab results, symptoms scores and questions, and the clinician reviews. If everything is okay and the patient doesn't want to see the doctor, they just schedule the next follow-up in 6-12 months."

We also face new threats, the magnitude of which is still unknown

Epidemics
At the time of writing, more than 2 million cases of COVID-19 have been reported to the World Health Organization and more than 155,000 people have lost their lives. Epidemics are able to move faster and further than in the past, due to globalization, greater connectivity and denser cities. "A new HIV, a new Ebola, a new plague, a new influenza pandemic are not mere probabilities … The only major uncertainty is when they, or something equally lethal, will arrive," the WHO said in 2018.[14] COVID-19 was first reported to the WHO on 31 December 2019 from Wuhan, China; within eight weeks, it had reached six out of seven continents.

Climate change
Climate change threatens food supplies, increases the risk of exposure to extreme weather and wildfires, creates favourable conditions for the transmission of disease, and exacerbates the effects of air pollution. "The life of every child born today will be profoundly affected by climate change," wrote *The Lancet* in 2019. "Without accelerated intervention, this new era will come to define the health of people at every stage of their lives."[15]

Air pollution
Outdoor air pollution causes 4.2 premature deaths annually.[16] By 2060, it is projected to prematurely kill 6-9 million people worldwide each year, and cost 1% of global GDP as a result of sick days, medical bills and reduced agricultural output.[17]

+ **4.6%**
of global carbon dioxide emissions are produced by the healthcare sector — higher than both aviation and shipping[18]

THE FUTURE OF HEALTHCARE

What about the people?

Technology will support the healthcare workforce of the future, but it will not replace them.

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"We can provide all this great technology, but the patient will always be a human. A human connection is part of the healing process"

Kevin Cassidy, WSP

Health is one of the least automatable sectors — according to management consultant McKinsey, only 36% of activities can be automated, predominantly data collection and processing.[19] Clinicians will still be needed to care for people, to interpret and contextualize sensitive information and to explain the choices available.

But as workplaces, today's hospitals leave a lot to be desired, says Mike Lovas at Healthcare Human Factors. "Different types of work happen in a hospital — consulting with patients, doing physical examinations, preparing medication, communicating with colleagues, providing education — all with different demands. But hospitals typically have limited function. There's a case room with a bed and a computer, and there's the hallway. Clinicians flip fluidly between different contexts, but they often just do the work wherever they can find space. Hospitals, especially older ones, are not optimally designed for the variety of work that takes place there."

Not having the right kinds of spaces means activities take longer, and increases the likelihood of mistakes. "When somebody's carrying out a high-risk task, like administering certain medications, they absolutely cannot be distracted," says Lovas. "The physical design of spaces can go a long way in supporting patient safety, specifically in the way that we allow clinicians to focus on critical tasks."

Clinicians can do the most good interacting with patients, but much of their time is often taken up with tasks elsewhere, or in moving between locations, especially in older facilities built for a different age. A 2018 survey used wearables and a sensor network to monitor contact time in a US intensive care ward, and found that nurses spent just 33% of their time in patient rooms, and physicians 15%.[20] So designers of new hospitals seek to devise more efficient, connected layouts. "We're looking to reduce the amount of steps

+ At the ProMedica Health Wellness Center in Ohio, HKS's design reduced average walking distances by 36%, or one minute and 55 seconds per patient encounter, a difference ranging from 28 minutes to more than an hour each day.

that someone has to take to do their job, and increase visibility so one person can monitor multiple activities," says Jason Schroer, principal and director of health at HKS in Houston, Texas.

This could extend to grouping services more logically, reflecting the way they are likely to be accessed, says Vivien Mak, director at P&T in Hong Kong. "If you're an outpatient coming back for a follow-up, you might have to go through five departments to see a doctor, have an x-ray, or a blood sample taken, pay for your medicine and collect it, and these might be in different buildings. If all of these facilities could be combined or put on a platform that is multidisciplinary in

"If a nurse spends 35% of their time walking to and from the medication room, and we can reduce that by half, that gives them more opportunity to care for patients"

Jason Schroer, HKS

Photo: Gareth Jones Photography

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"No robot yet has the capacity to sense a distressed client and propose offering him or her a glass of water or a cup of tea"

McKinsey Global Institute

terms of care, then the patient can come to a one-stop service centre."

Part of the problem is that healthcare estates have typically been developed piecemeal over many decades. "There have probably been quite a number of changes and additions, but they weren't done according to a masterplan," says Mak. "New blocks were built wherever was available, and the allocation of functions may not relate to the original block that well." For both new-builds and redevelopments, she says, a common approach is to group facilities for outpatients, in-patients and "hot zone" functions such as operating theatres and intensive care units (ICU), and allow more sustainable expansion. "It's becoming very important to plan for the future of these zones, and how they connect with each other."

It's rarely possible to shut down a whole hospital once it's running, so reforming the masterplan is a long-term endeavour. Mak is involved in two such projects at public hospitals in Hong Kong. "You need to devise a grand plan for the hospital to be redeveloped phase by phase over the coming decades. You need to identify, where you can, some space for decanting and then decide which block goes first."

In Hong Kong, there is also a move to separate elderly and acute care. Older

people with complex conditions requiring long-term care will be looked after in specialized infirmary units, freeing up acute wards. "When you design an acute hospital for all services, you have to facilitate circulation and connections with operating theatres and ICUs. But most infirmary care patients don't require those services, so it's more efficient to look after them in another setting."

Standardizing room and floor layouts could help to design out errors, she adds. This way, staff know automatically where to find the things they need: "No matter which floor staff move to, the logic is the same." This applies to workflows too: "Say you always go through a certain

Above Moxi by Diligent Robotics is designed to automatically perform the nursing tasks that don't involve interacting with patients, such as refreshing supplies

Photo: Diligent Robotics

procedure — you always greet the patient here, then move onto a certain function and so on — we devise a diagram that can be repeated across the hospital."

Better logistics can also free up staff time. Hospitals are complex networks of supply chains for items that must be delivered without delay or contamination. Gunnar Linder, regional director at WSP in Sweden, says a central equipment store — shared between different operating theatres with just-in-time delivery — frees up clinical space, cuts walking distances and reduces overall equipment requirements.

Any workplace design requires the input of the users, but time-pressed nurses are not logistics specialists. Linder's team has built a database of previous designs, "so they don't have to start from scratch. We can map those rooms to maybe 90% accuracy at the beginning and then use their time and energy to take it from there."

Lovas warns that "change fatigue" is very real in healthcare: "Frontline staff are used to old technology and siloed systems, they're full-on in terms of workload, and especially in academic hospital settings, they're constantly asked to do new things for different research studies. So there's a huge hurdle to be overcome to introduce new systems, technology or models of care."

THE FUTURE OF HEALTHCARE

Smart hospitals aren't just more efficient.
They can help people heal faster too.

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*"If you're running a 100-bed hospital and everybody is leaving
one day earlier, that's a significant saving"*

Simon Kydd, WSP

P20

Healthcare has been slow to capitalize on the opportunities that digital technology offers, be it generating new insights by combining data sources or automating building functions. This is partly because of the need to protect highly sensitive patient data, says WSP's Nolan Rome. "That was a barrier to healthcare being able to leverage technology in the same way as other sectors. Before there would have been a public network and a vendor network for all the public systems, the HVAC controls, the infotainment and patient wifi access, and all the secure data would be on a separate network. We're becoming much more sophisticated around that — now in most cases, we can

converge all of the systems onto a single platform, protected by software security. That's unlocked so many opportunities. We are helping owners to integrate all of the systems that they already have, and use those to make their business more resilient, whether that's around energy savings and sustainability, or to make nurses and doctors' lives a little easier, or to make more informed decisions about how their business will operate five years from now."

For many technologies, the business case wasn't always easy to quantify, but that's changing too. Integrating systems and harvesting their data allows owners to take a step back and examine whether or not investments are working as they should, says Rome. "When you're making decisions about patient rooms that you'll have for the next 30 years, what information do you need to decide whether an investment has been successful or to make

improvements? We can measure how a patient infotainment system is used by clicks and time spent, to look at whether people are ordering food or looking at their patient data, or whether they're just breezing right through that to get to the next movie. If they're not, you can then look at why not. We can do that across the 250 or so systems installed across a hospital to build an umbrella strategy to understand if these systems are being used in the best way possible."

Making physical changes to a hospital is disruptive and hard to reverse; technology allows constant, incremental updates in response to real-time conditions. "With software, you can play with it behind the scenes and test it before pushing it out," says Rome. "There is still some cost, but it's not like changing the built environment, where there's infection risk, downtime and loss of revenue."

Automated building systems and seamless information transfer don't just make running hospitals easier. They also improve the experience for patients and their families. For example, providing them with better information before and during their visit can make it less stressful, says Simon Kydd at WSP. This could be delivered direct to their smartphone or tablet via an app. "The app would know what time you need to be there and it knows where you live, so

This page The Hospital for Sick Children in Ontario (left) and Phoenix Children's Hospital, designed by HKS (right). Smart devices will be integral to future healthcare facilities, for entertainment as well as clinical and building functions

Photo: Richard Johnson Photography

Photo: Blake Marvin / HKS

THE FUTURE OF HEALTHCARE

it could tell you about different transport options and let you know what the traffic will be like at that time of day. If you decide to drive, a parking space can be made available. The app can show you what entrance to take, how you need to sign in and which waiting room to go to — all the wayfinding can be done on your device. And if your appointment is delayed for whatever reason, the app can reassure you that your car parking stay has been extended, so you don't have to worry about getting a ticket."

The applications of this technology in a clinical environment are potentially even more valuable — as when combined with RFID tags, for example. "If a physician or a caregiver with a radio frequency chip on their badge walks into the room, the system instantly knows they are there and their picture could pop up on the TV screen," says Jason Schroer at HKS. "If patient wristbands also incorporated RFID tags, building systems could automatically set the lighting or temperature to suit their preferences. Hospital managers could look at a map of the facility and know exactly where everybody is, and you could do the same with medical supplies. Traditionally those systems were set up to just track where things are, but now we can use them to study how people are actually using the spaces and

Photo: David Barbour

make adjustments. As designers we're interested in that technology because we can learn from it by observing behaviour. From a client's perspective, it's a way to manage their resources more effectively."

Rome, meanwhile has been working on a project in a children's hospital, which shows another clinical application of responsive buildings. "We asked some clinical psychologists and paediatric nurses if it made a difference whether the nurse is in the room or not, and they said it definitely did. Children are much more apt to share how they're feeling with their tablets and phones — those

are their security blankets, that's how they get their entertainment, that's where they message their friends." So they built a patient portal app where younger patients could adjust their room controls, but also record how they were feeling. "It gives nurses and doctors an indication of their overall wellness so that they can engage the patient at the right time, as opposed to just coming in on a set schedule to take their pulse and temperature. If they can see the patient is improving, they might wait for 30 minutes and spend that time helping another patient."

Ultimately, designers hope to use smart technologies to create environments that promote faster healing. Wellness and biophilia have become major preoccupations in new buildings, and various studies have shown that views of nature, fresh air and daylight can improve outcomes, increase pain thresholds and shorten hospital stays — by as much as 20%. Smart buildings can supplement these effects or recreate them in internal spaces such as intensive care units. "It could be as simple as reducing the amount of noise in the room so people can sleep better, which speeds their recovery," says Kydd. Nurse calls can be sent directly to handheld devices, rather than activating buzzers or lights that disturb other patients. "That device

Above Views of nature are becoming an important feature of healthcare facilities. Alder Hey Children's Hospital in Liverpool, UK has been designed by architect BDP as three fingers radiating out from an atrium to maximize connections with the landscape

will tell the nurse to go to a particular patient and exactly what they require."

As individual patient rooms have replaced long wards with high windows, some opportunities for daylight have inevitably been lost. Other types of room are sealed from the outside to control infection or protect specialist equipment. Tunable LED lighting can compensate by mimicking daylight patterns to calibrate the body's internal clock. The same technology can also help staff working antisocial hours or very long shifts, says Schroer. "We can tune the lighting to mimic a better circadian cadence, and that could help to manage alertness and fatigue." A study by HKS' research arm CADRE found that nurses who could see daylight were able to maintain a higher cognitive level. "The next piece, which is harder to prove, is whether that then leads to fewer medical errors — logically, if you're more alert and less fatigued, you're less likely to make an error in patient care."

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"We're seeing a huge merging of hospitality with healthcare, particularly in the US," says HKS's Jason Schroer. "In health systems where there is choice, we're hearing terms like 'retail health' or 'healthcare consumerism'." In a hotel room, the guest can control the lighting, the air-conditioning, the entertainment; they can order room service. "That's becoming part of the expectation in healthcare. It's a big jump in terms of the capabilities of patient rooms and it's more and more prevalent."
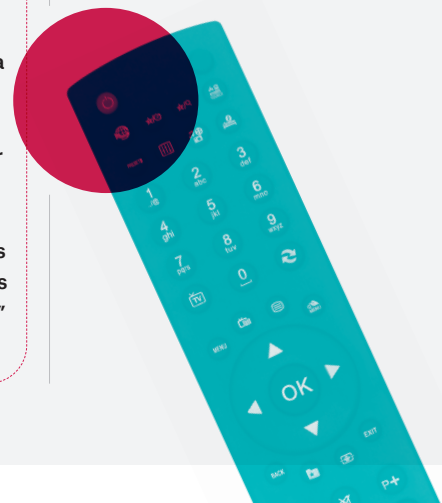
THE FUTURE OF HEALTHCARE

Cleveland Clinic is a world leader in healthcare, with a US$2.5bn global construction programme. **So what does it think the future looks like?**

Cleveland Clinic is many things. It's one of the largest and most respected hospitals in the US, ranked the second best in the world by *Newsweek*. It's a non-profit academic medical centre with an operating revenue of over US$10bn. It is employer to 67,500 caregivers worldwide, skilled in 140 specialties. It's 6,026 beds spread over a 165-acre campus near downtown Cleveland, Ohio, as well as 11 regional hospitals, more than 220 outpatient facilities, and locations in south-east Florida, Las Vegas, Toronto, Abu Dhabi and London.

Yet no matter what part of this vast health system its 2.4 million annual patients visit, they will find a distinctive look and feel. "We're very focused not only on the patient experience, but also that of the caregivers," says executive director Pat Rios. "If the caregiver is positively impacted by the built environment, they're going to give the patient a more positive interaction and a more direct, tangible sense of wellness."

> **"We want to let in as much light as possible, but windows are not as thermally efficient as walls. So that requires a lot of thought"**

Rios directs management of Cleveland Clinic's 3.4 million m² facilities and real estate portfolio, as well as its $2.5bn global construction programme, working with Christopher Connell, who joined in 2017 from Foster + Partners as chief design officer. Connell is responsible for making sure that the physical space provides the right type of healing environment, and Rios is the person who makes it happen.

The Cleveland approach might be characterized by thoughtfulness, coupled with an extreme attention to detail. "We're known for a very clean design. It's not just about the white and the grey, it's in the most subtle details — if you look at the ceiling, you'll see that the sprinkler heads, the lights and the detectors are all lined up so it's very symmetrical, very crafted."

This lack of clutter is reassuring for the patient, but also efficient for the caregiver, Rios says. "They have access to what they need quickly so they can go in, do what they need to,

and then let the patient focus on healing and resting." Unusually, all patient facilities are outward-facing, so they feel connected to exterior spaces. The rooms are "optimally" sized, says Rios, "from an operational perspective, but also so that the patient doesn't feel confined or like they're just moving through a process." In Avon Hospital, Ohio, the beds are arranged so that a nurse walking past a patient's room can easily see their face. "It's a visual check on health. The caregiver can just walk down the hallway and see all the patients without having to disturb them."

There are tensions that need to be resolved — on energy, for example. "We want to let in as much light as possible, but windows are not as thermally efficient as walls. So that requires a lot of thought." In the recently completed Taussig Cancer Centre, for example, there is floor-to-ceiling glass curtain walling, but the energy cost per ft² is still

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THE FUTURE OF HEALTHCARE

> **"The floors are very thick and each wall is isolated by wall blocks … all of that is about creating an ultra-quiet hospital"**

low thanks to features such as heating that is targeted on where the patient will be — in an infusion chair, say — rather than the whole space. "It's using heat when the patient needs it, but also connecting them with the environment."

At Cleveland's new 185-hospital in London, due to open in 2021, even the building structure is part of creating a serene environment. "The floors are very thick and each room is isolated. It's not just the concrete flooring — each wall is isolated by wood blocks, then the screed flooring is isolated room to room, and all the jacks are offset from each other so there's no sound conductivity. The detail of the insulation, the amount of dry wall, the panelling — all of that is about creating an ultra-quiet hospital."

Of course this standard of product costs more — although not necessarily as much as you would think. When Rios joined three years ago, he conducted a benchmarking exercise of Cleveland's projects, and found that the construction cost per ft² was below the industry median. He puts this down to the way it approaches project delivery: Cleveland nurtures long-term relationships with core partners, and remains closely involved through its model of owner-controlled project delivery. "Particularly with technically complex projects, you need to manage it as an owner." On one project, Cleveland used an integrated contract, where the designer, constructor and key trades had a profit-sharing agreement with a target value delivery. "It was fascinating how much that changed behaviours. I think a joint-risk continuum is going to be the future for this industry."

As well as new projects, Rios is also engaged in renewing the clinic's older buildings. Renovating older spaces

usually includes meeting much higher life safety standards, boosting wireless bandwidth to serve nurse and patient tracking systems and installing cabling for power and data. "Technology integration is an incredible challenge. Not a lot of it is bespoke, you're just buying a bunch of commercial off-the-shelf stuff and assembling it into a kit that works." Rios' team install new data and power equipment in overhead areas, as well as reconfiguring the heating, ventilation and air conditioning systems that support it — but all without taking too much space from clinical functions. "We want to renew the facility, give a greater capability, but also deliver the same or better clinical throughput. Nobody wants to invest in a new technology that cuts revenue."

Left Clean lines and uncluttered details define the careful brand aesthetic — whether in a patient room in the new London hospital (above) or Frank Gehry's characterful design for the Lou Ruvo Center for Brain Health in Las Vegas (below)

Opposite The main campus in Cleveland, Ohio, which has 1,300 beds spread over 165 acres

So how much future change do they try to anticipate on new projects? "As we're programming facilities, we definitely have an eye for how much column space we need, how the rooms are set up — we don't have a future use in mind, but we do think through how to optimize it for future use." As for technology, Rios anticipates further increases in demand for power and data. "We try to imagine, within currently available technology, what capabilities we need to build into the building — so, larger trays, more power, slots for extra back-up generators. You have to balance it. In a lot of cases we're willing to spend money upfront to extend life cycle."

Rios' team is in talks about the technological vision for a 400,000ft² neurological institute on the main campus, anticipated to begin design in 2021. "The institute chair wants patients to be able to go through different tests as part of the entry experience. They walk in, they pick up a patient tracker, and their gait is filmed as part of the natural process of moving through the building. They might have to fill out a form with a pencil and it would log how hard they squeeze it. So the clinician already has a view of their capabilities when they get there, which means they don't have to go through a physical exam."

Telemedicine or virtual medicine is another exciting development, though Rios says it will be important to "right-size" it so it is only used when appropriate: "We're still working on it. We're trying to create the infrastructure, but simultaneously figure out how it's going to impact our care delivery in the future. It obviously has impacts from beginning to end of the process, so we're still thinking about how that's going to work."

The patient is becoming the point of care.
Enter Telemedicine 2.0.

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"COVID-19 will expedite the transition to a telemedicine environment. We are piloting and clinically validating products in real time"

Michael Crawford, Howard University College of Medicine

Telehealth has been one of the fastest growing parts of the healthcare sector, with a range of new apps and devices to serve a patient base that is increasingly tech savvy. The millennial generation and younger, in particular, are comfortable with digital interaction, and demanding that providers allow them to access services in this way.

For patients, the prospect of video consultations with clinicians is more convenient than taking time to go to the hospital, especially for routine check-ups or minor conditions. For providers, helping patients to better manage conditions at home through remote monitoring and automated reminders offers a way to reduce the burden of chronic disease and demand for medical intervention. The COVID-19 pandemic has accelerated this trend, as governments around the world urge their citizens to stay at home, and for only the most severe cases to attend hospitals.

"Telemedicine will be a critically important access point," says Michael Crawford, associate dean for strategy, outreach and innovation at Howard University College of Medicine in Washington DC. "It's not only how we leverage telemedicine and remote monitoring in a pandemic, it's how we should deliver care, period."

Data will be the key to future medicine, he believes. By integrating

health, social, financial and environmental data across disparate platforms and applying artificial intelligence and machine learning, we will be able to better track infectious disease or flag patients at risk. "If people have been instructed to self-quarantine for 14 days, we could evaluate them based on historical data, and start to create personalized, real-time interventions. If an individual's biometrics deviate from the normal pattern of recovery, we could proactively deploy resources to address the issue."

The only way to deliver care to people in their homes is to understand how they function within their home environment — their natural habitat, he adds. "If we are capturing a patient's activity patterns and evaluating their heart rate, blood pressure, breathing patterns, sleeping levels from a wearable device or sensor, then we can observe if they are trending in the right direction or when a medical intervention would be appropriate." Patients could be sent a message to check in, or in more serious cases, a medical professional sent to their home.

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Faster network connections between hospitals will enable experts in different places to collaborate during procedures — and even to operate on patients remotely. For example, in 2019, the CorPath GRX robot (below), developed by Corindus, was used to perform the first remote heart surgery — on a patient 20 miles away — in Ahmedabad, India. Virtual and augmented reality could also allow surgeons to view scans or anatomical data superimposed on a patient, or to control a robot that is carrying out an operation somewhere else.

Photo: Corindus
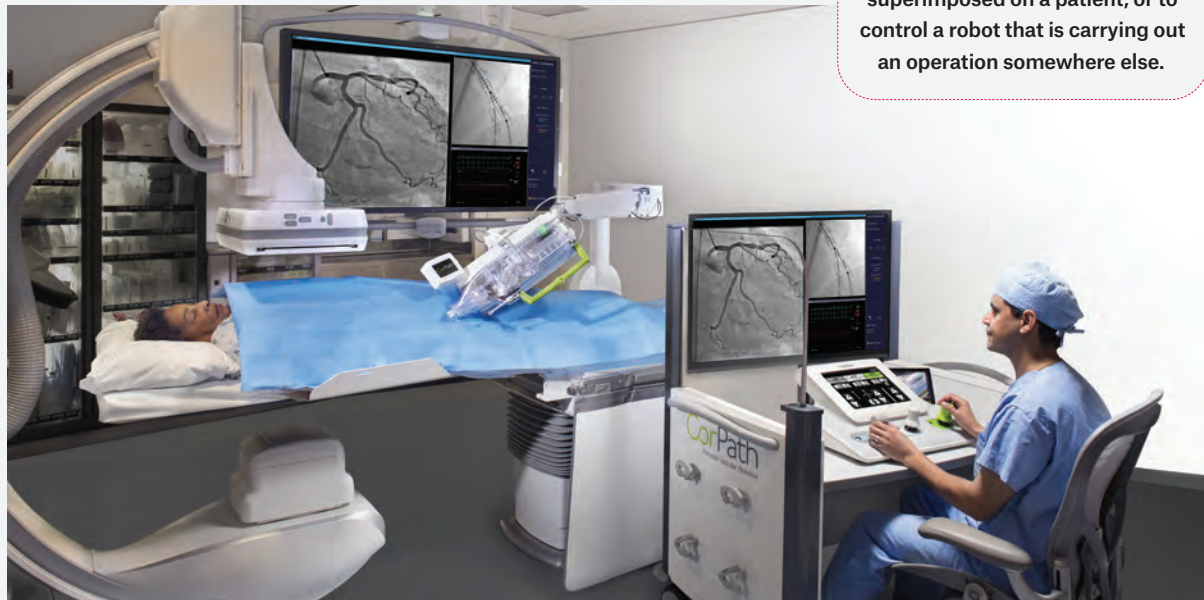
DRONES TO THE RESCUE

The most important thing is the quality of the data, says Crawford. "If you have an integrated historical data set, collecting new information provides different insights regarding an individual's health and enables you to personalize interventions. If we had this infrastructure in place today, we could be more efficient, strategic and prudent in our resource allocation in addressing a pandemic."

But — and it's a big one — telehealth's potential will only be realized if it's targeted at the populations that have the greatest incidence of chronic disease: "When we are referring to vulnerable patients that are susceptible to COVID-19, a disproportionate amount reside in medically underserved communities." These are exactly the communities that find themselves on the wrong side of the digital divide, lacking

Ultra-high-speed 5G networks will underpin another feature of healthcare's not-so-distant future: drones. These could make a real difference to outcomes in remote areas, where they could deliver medications or defibrillators — the probability of surviving a cardiac arrest declines by 10% with each passing minute.[22] A Swedish trial found that 5G-based drones could reach the scene of an emergency four times faster than an ambulance.[23]

In Canada, about half the population live in major cities, with good access to healthcare. The other half do not. "In the interior of British Columbia, last year there were over 800 incidents where it took more than 45 minutes for a first responder to get to somebody who was in a life-threatening situation," says Kevin Cassidy, head of healthcare at WSP in Toronto. "Can we use that technology so that if I have a heart attack on a mountain, a drone is dispatched

right away so my friend could care for me while the paramedics are en route? Getting that reaction time down could save somebody's life."

In 2019, a trial using a 4G LTE cellular network provided by Ericsson allowed drones to fly 80 miles while being piloted from 3,000 miles away in Vancouver. Moving to 5G would allow an even further leap in capability, supporting many simultaneous drone flights and greater accuracy.

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An Accenture survey of nearly 8,000 people across seven countries found that 47% would prefer a more immediate, virtual appointment over a delayed, in-person appointment [21]

the resources and technical literacy to fully participate online.

Howard University is seeking to address this with its 1867 Health Innovations project — Crawford is inviting tech entrepreneurs, innovators and corporate partners to develop scalable models for this demographic over the coming months. Solutions are likely to be delivered over cell phones, but Crawford expects them to depart from existing products in various ways. "The clinical pilots will likely reveal that minor modifications in content, interfaces and tech that better align with individuals' care needs. The interface might look different, the content might be worded

differently, the instructions and manual might look different, the things that you have prioritized might look different for a chronically ill population."

When super-fast 5G networks, high-definition video conferencing, and ubiquitous sensors are a reality, it will also radically reshape the healthcare landscape. Outpatient clinics are likely to become a thing of the past and only the most serious conditions will necessitate a trip to hospital. "Historically, hospital visitors have been a mix of the semi-sick to those will really serious illnesses," says Jason Schroer at HKS. "We're seeing a slow shift to the hospital becoming a place for only the sickest of the sick."

Photo: Doctor on Demand

THE FUTURE OF HEALTHCARE

Technology brings universal access nearer.

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"In Africa, innovation is about balance, about the approach rather than the materials or technologies. It's about thinking what will suit a specific community best"

Laura Swanepoel, WSP

In large, less urbanized countries with underdeveloped healthcare infrastructure, a decentralized model with telemedicine at its heart will be essential for expanding access. Here, there is arguably an even greater opportunity to build digital services from scratch, unencumbered by legacy infrastructure or systems. A Philips study of global healthcare systems found that emerging economies are leading the way — it identified China, Saudi Arabia, India and Russia as forerunners in the use and adoption of digital health technologies to plug the growing gap between existing provision and rising demand.[24] "In rapidly growing economies, there's more expectation of healthcare," says Simon Kydd at WSP. "Where 20 years ago, somebody would have been prepared to travel 50 or 100 miles to go and see a GP, now they expect that service on the doorstep."

Building physical infrastructure such as hospitals and roads is a relatively slow process, far outstripped by the proliferation of mobile devices and networks. Africa has just nine hospital beds per 10,000 people (compared to 62 in Europe),[25] but a mobile phone penetration rate of 44%. By 2025, it is predicted that 66% of the population will have a smartphone and 39% will use the mobile internet.[26]
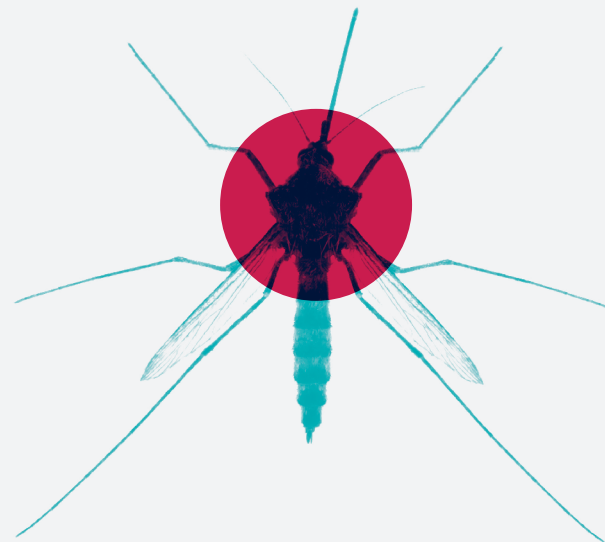
"Improving access to healthcare in Africa is a massive task," says Laura Swanepoel, office director at WSP in Johannesburg. "Many remote areas are well populated, but access is severely limited or lacking entirely." Meanwhile, major hospitals in urban centres are struggling to meet demand as people move to cities. Just as elsewhere, the rate of non-communicable diseases is rising, alongside a high incidence of diseases such as HIV, malaria and tuberculosis and two-thirds of maternal deaths globally.[27]

The future of healthcare in Africa isn't about overlaying a Western template, she stresses. "Africa has major pipelines

SUPPLIES IN THE SKY

Drones are already delivering medical supplies in Rwanda, Ghana and Tanzania, and testing is underway in Malawi and South Africa. As of May 2019, more than 65% of blood deliveries in Rwanda, outside Kigali, were flown in by drones operated by San Francisco-based company Zipline (left). "This technology is growing very fast in Africa," says WSP's Jabulile Nhlapo. "At the moment, it's just one-way delivery so the drone will drop off the package but not land, but they're developing it for back-and-forth deliveries." That means hospitals and clinics will need launching, landing and charging facilities, as well as airport-style control systems linked to building management systems, says Nhlapo. "It's only a matter of time before this technology becomes part of standard medical practice, and it's really going to change how we look at healthcare facilities."

Photo: Zipline

The new Middelburg District Hospital in Mpumalanga, South Africa will initially have 220 beds, but can expand to 350 as the population grows. WSP's multidisciplinary team specified energy-efficient lighting and low-energy services, as well as water meters to help monitor usage and identify leaks. Here, sustainable design is essential for resilience, says WSP's Laura Swanepoel. "In many parts of Africa, there are major issues with water and power. That makes the case for green building practices much stronger so that healthcare facilities can be self-sufficient in the event of an outage. The upfront cost may be a little bit higher, but the return on investment is quick and easy to prove."

Lead architect Sanele Mwelase at Geyser Hahn believes design norms need to change: "Patient comfort comes first, but we need to reduce the services needed to run the hospital," he says. "This means not only the building shell, but the medical equipment. Water scarcity will stop a hospital, but healthcare cannot go offline. The benefits of maintenance-free, zero-emission buildings could be absolutely critical in the medical sector."

of wealth and the capacity to deliver amazing projects, but at the same time, there are communities where the whole plan needs to look a little bit different."

Mobile technology and drones could support a decentralized model, connecting small clinics to expertise in larger centres. For example, a telemedicine hub at the new Middelburg District Hospital will extend its reach far beyond the immediate catchment, says Jabulile Nhlapo, mechanical engineer at WSP: "Someone sitting in a primary healthcare facility in the Eastern Cape should be able to easily communicate with a tertiary institute to get advice on a particular case or for consultations."

"Natural disasters are the new norm. We have to look 50 years ahead to design for this ever-changing environment"

Sanele Mwelase, Geyser Hahn

Visualization: Geyser Hahn

THE FUTURE OF HEALTHCARE

Prepare for the unexpected.

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*"Uncertainty is the only certainty there is,
and knowing how to live with insecurity is the only security"*

John Allen Paulos, Temple University

What do we know so far? Hospitals need to be bigger, and to cope with surges of sudden high demand. In the longer term, they will probably shrink, but offer more specialist care for the sickest patients. They need to be more human, but also smarter, more automated, connected and highly serviced. They will host technologies that haven't been invented and treat diseases that have yet to be diagnosed. They will have to do this against a backdrop of pandemics, climate change, extreme weather, and shortages of water, power and resources.

Beyond that, all bets are off. The buildings we are designing today may not be ready for a decade, and have to stand in some form for a century or more. So they must be robust and, above all, flexible. The problem is that it's hard to predict exactly what kinds of space will be needed, says Simon Kydd at WSP. "Technology is developing rapidly, and everything you read about is within touching distance. Will we need lots of bunkers for radioactive treatment, or laboratories that take our blood, engineer it and put it back? We have to design

buildings that are at the forefront, but future-proof for as long as possible."

We know this is important because we are living with the consequences of inflexible design. As in many developed countries, Sweden's healthcare estate comprises many buildings from the 1960s and 70s. "They are not up to the standards for the healthcare of the future, so providers have a lot of space that they can't use," says WSP's Gunnar Linder. "It's too narrow and the span from the floor to the ceiling is too low. Today the equipment is so integrated

into the building that you need to build in a different way. MRI scanners, for instance, are getting more powerful and that means they are bigger and heavier, so you have to have a really strong foundation. And they also need a lot of space, which requires a broad span between the piles."

Adapting these older buildings to meet modern healthcare standards usually requires compromise. Converting the space to other uses such as offices is an option, but there's a limit to how much office space a hospital needs.

PANDEMICS, EARTHQUAKES AND OTHER DISASTERS

Hospitals need to be resilient, in every sense of the word. In the event of a pandemic, sections of a hospital need to be sealed off to prevent cross-contamination, but until then, they need to function normally. "We need to set the space up in a smart way so that it's there if there's a major incident, but it's not wasted at other times," says Suzanne MacCormick at WSP. For the redevelopment of Kwong Wah Hospital in Hong Kong, for example, there is a 140-bed

isolation facility designed to be negatively pressured — a ventilation technique that allows air to enter but not to escape — and 100 beds that are convertible from normal to isolation mode.

As the global population grows, exposure to natural disasters is increasing too. Many of the world's major cities are located in areas prone to flooding, storms and earthquakes, and urban development worsens their impact by degrading natural

barriers. Climate change is also increasing the frequency of extreme events. Healthcare buildings need to withstand disasters themselves, as well as being able to care for those affected. "Resiliency is more and more part of the design solutions that we're working on with clients, particularly those in coastal areas," says Jason Schroer at HKS. "You can't completely proof every building against every disaster, but there are certain measures you

can take to mitigate risk." Patients and their carers have to be able to shelter in place, for example, so to protect against rising sea level, critical areas or infrastructure might be elevated. HKS also designed a hospital in Joplin, Missouri, to replace one that had been destroyed by a tornado. "We hardened the core and within that we provided infrastructure such as medical gases, so that they could bring patients in from perimeter rooms."

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In 2019, there were at least 396 natural disasters, affecting over 95 million people and costing nearly US$130 billion [28]

THE FUTURE OF HEALTHCARE

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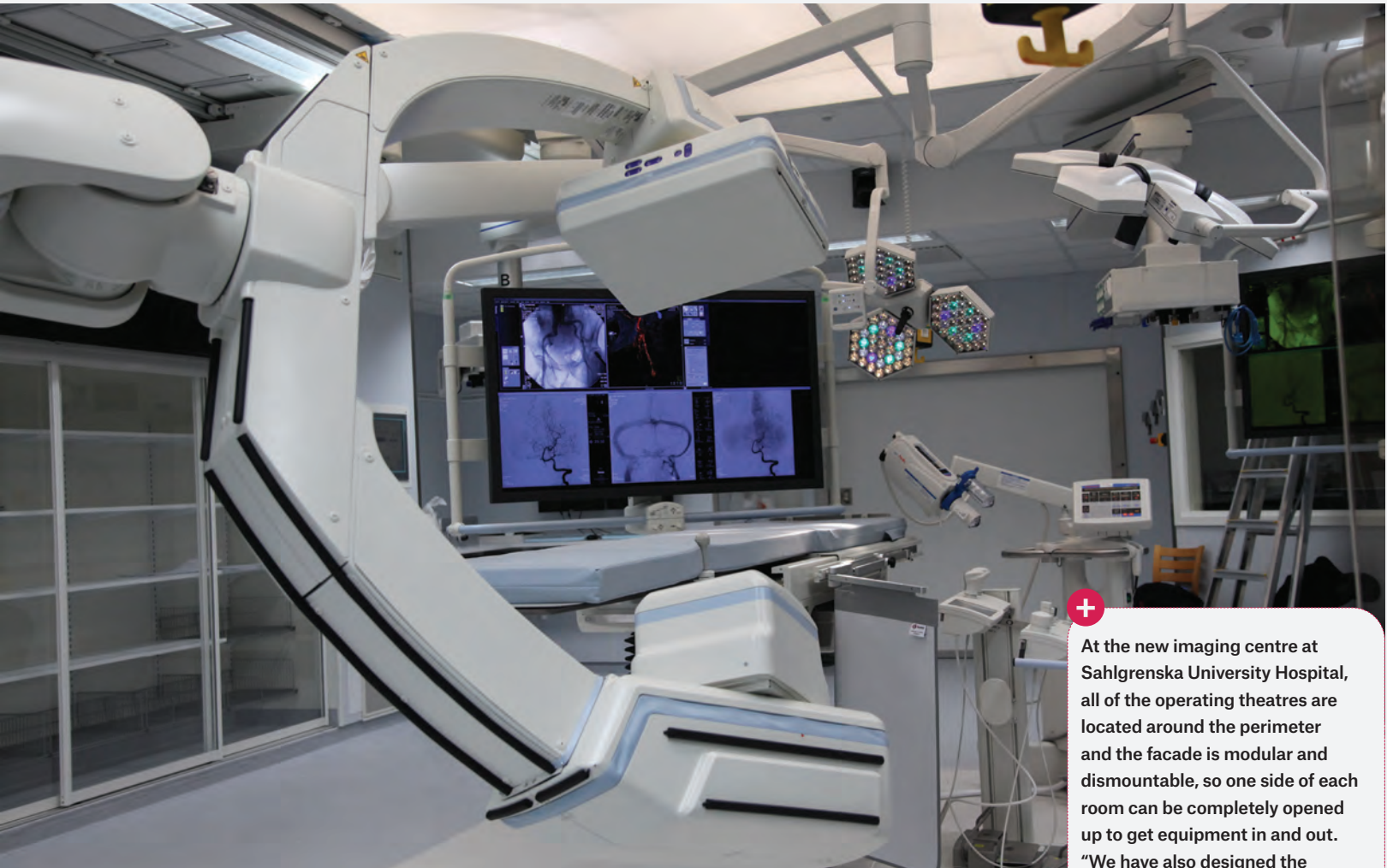
At the new imaging centre at Sahlgrenska University Hospital, all of the operating theatres are located around the perimeter and the facade is modular and dismountable, so one side of each room can be completely opened up to get equipment in and out. "We have also designed the electrical and ventilation systems so that everything in the operating theatres can be sealed off," says Gunnar Linder at WSP. "So you can access an operating theatre from outside to rebuild it without affecting other areas. You can have a construction site within a fully operational ward."

Selling it off to pay for new development is another — but there are not many types of building that can be comfortably collocated with a working hospital.

There's no sure way to tell what kind of technology today's hospitals may have to accommodate over their long lifespans, but there are ways to make them more adaptable. "When we're building something, we need to look at what that space could become in the future," says Suzanne MacCormick, director of global healthcare business growth at WSP. "You're almost doing a double design, which does have a cost implication upfront. But in our analysis we've found that, in almost every case, it breaks even at the first change." Buildings designed on a grid layout and made from component parts precision-engineered off site, and with an up-to-

date digital twin, could be reconfigured far more easily, for example. MacCormick suggests that one possible use for a redundant outpatient department would be as assisted living space for older people, as it would have good access to care. "They would have instant access to therapists and healthcare. But we also need to make sure that the space can be equally well accessed from a separate route, not just through the hospital."

Healthcare is already becoming a component of more mixed-use developments, says Jason Schroer at HKS. "You might have a clinic, but also retail, hotel, places to live. We are seeing a trend for blending these together. Hospitals have been designed to be very inward-focused, but this is requiring us to think about them in a different way. In some cases, health buildings are becoming anchors to development."

Photo: Lisa Persson
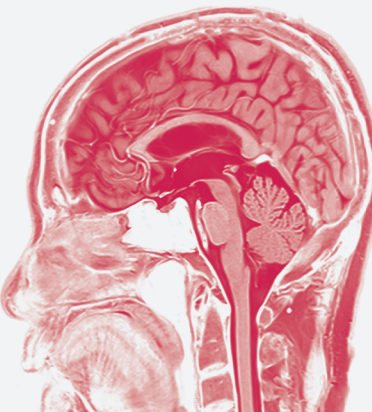
Healthy cities are the most powerful tool we have.
Prevention is better than cure.

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"Regardless of the country, the evidence about what shapes the health of the population is pretty consistent, and healthcare isn't the biggest determinant"

Chris Naylor, The King's Fund

Smart technologies can only go so far. The only realistic solution for the future is to keep people healthier for longer — which means reshaping the urban environment in a way that promotes health rather than hindering it.

"Cities concentrate people and resources in one place, which creates hazards but also very real opportunities for improving health," says Chris Naylor, senior policy fellow at UK health charity The King's Fund. Naylor, who has researched the role that cities play in health around the world, says that more than half of the variation in population health is down to three key determinants: the environmental and social conditions in the places where we live, our economic situation, and our behaviour and lifestyle. [29] "Cities play a really important role because they influence all three. We should be creating compact, walkable, mixed-use developments that encourage social interaction and make it easier for people to be active. We should be doing everything we can to inspire and enable healthy eating, and to create places for play and leisure for all ages."

Are successful cities inherently unhealthy? In *The Economist's* latest index of the most liveable cities, Tokyo is the only large city ranked in the top ten — the rest are small or medium-sized, led by the Austrian capital Vienna. [30]

Neither is there any crossover at all with the 20 most dynamic cities in JLL's City Momentum Index, which is dominated by India and China. [31] But there must be an intersection between health and success, says Naylor — "If you have a really unhealthy population, that's bad economically in terms of reduced productivity, absence from work and welfare expenditure." The global depression looming as an indirect result of COVID-19 is ample evidence of the economic importance of good health.

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City leaders are playing an increasingly influential role, often ahead of national governments. Polluting vehicles, unhealthy foods and smoking may be legal, but they are being made unwelcome in various forms at city level.

● In Paris, the most polluting vehicles are banned from entry and whole areas are car-free on Sundays

● New York's introduction of mandatory calorie labelling in 2008 helped pave the way for federal adoption later on; its 2002 ban on smoking in public places has yet to reach federal level

● In Berlin, every year the amount of space given to cars decreases and the cycle network increases

● Amsterdam's Healthy Weight programme prohibited advertising of unhealthy food targeted at children, and only tap water and healthy packed lunches are allowed in primary schools

The emerging science of wellness is starting to yield an evidence base on the relationship between health and environment. Building standards such as WELL and Fitwel monitor aspects such as biophilia, ergonomics and whether a building nurtures mental health. Studies in office environments have found that good ventilation can increase cognitive scores by 101%, for example, or that workers seated next to windows sleep for 46 minutes longer at night. [32] The WELL Community standard, launched in 2017, applies these principles across whole districts.

As cities become smarter, urban designers will have many more tools to improve outcomes. "Once we have high-speed wireless networks, and people are wearing devices tracking their health data, we will be able to use AI and rich data sets to promote health and wellness," says Kevin Cassidy at WSP.

In Copenhagen, city authorities have collected data on pedestrian and cyclist movements for years, providing quantitative evidence for policy making. "In many cities, this kind of detailed data is simply unavailable," says Naylor. "If cities are to reorient planning and other activities to place greater emphasis on population health, this must be reflected in the types of data they collect — what matters must be measured."

Planners and designers should prioritize the social determinants of health as they develop tomorrow's smart cities, says Howard University's Michael Crawford, addressing factors such as transportation, food security, job opportunities, affordable housing and safety. "If you do not have access to nutritious food, diabetes medication alone will not help you effectively manage your condition. If you have a prescription but no pharmacy within your community, what good is that prescription? Technology can help address some of these barriers."

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INDEPENDENT CITIES: BETTER FOR OLDER PEOPLE, BETTER FOR EVERYONE

Older people will be a much larger group in future cities, and so we will have to design places that support them to remain healthy and independent. But it's not only older people who need a sense of community, to rest occasionally or use a public convenience. Narrow pavements, fast-moving traffic and air pollution can make any of us reluctant to walk, let alone cycle, and poor signage or obstructions make it hard for everyone to navigate urban environments. By analyzing how the most vulnerable members of society navigate a city, it can reveal important design lessons that would benefit us all.

"No matter how beautifully we've designed a hospital, it's still a hospital," says Vivien Mak at P&T in Hong Kong. "If people can stay in the community, they are socially engaged and more active, and that slows down the deterioration and hopefully keeps them healthier." In Hong Kong, the proportion of the population aged over 65 is expected to increase from 16.6% in 2016 to 36.6% by 2066. Mak's office was commissioned by the government to produce the Elderly-friendly Design Guidelines, to inform decision-making on new developments. These are structured around four overarching principles: environments that are safe; that foster independence and confidence; that support cognitive ability and reduce anxiety; and that promote wellbeing and contentment.

"If older people find it difficult to find a place or they don't enjoy the experience, they won't go out," Mak points out. "If the walk from their home to the grocery store takes half an hour, they probably have to take a rest a few times during the journey. If you provide sheltered seating spaces where they can chat with their friends, they may be happy to do so." Some features of the urban environment can make it all but impossible for anyone less able to get around. "In Hong Kong, we have a lot of elevated crossings, but if they don't come with an elevator, it's hard for older people to climb those flights of stairs." Other examples include pedestrian crossings that don't leave enough time for older people to reach the opposite side, or level changes that can trip them up. Unclear signage or bland places that all look the same can leave them confused, she adds. "For example, an all-white floor, with white walls and white ceiling may be confusing because they can't see where the floor ends and the wall begins. If it's the other way round, with very strong floor patterns and big contrasts that young people like, that can make older people feel dizzy." ⊗

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Doctors are prescribing walks in nature for patients suffering from chronic conditions. The Park Rx America platform lists **10,000 parks** and has **500 registered "prescribers"**, who can set the frequency of visits, text reminders and check how often the patient has "filled" their prescription. [33]
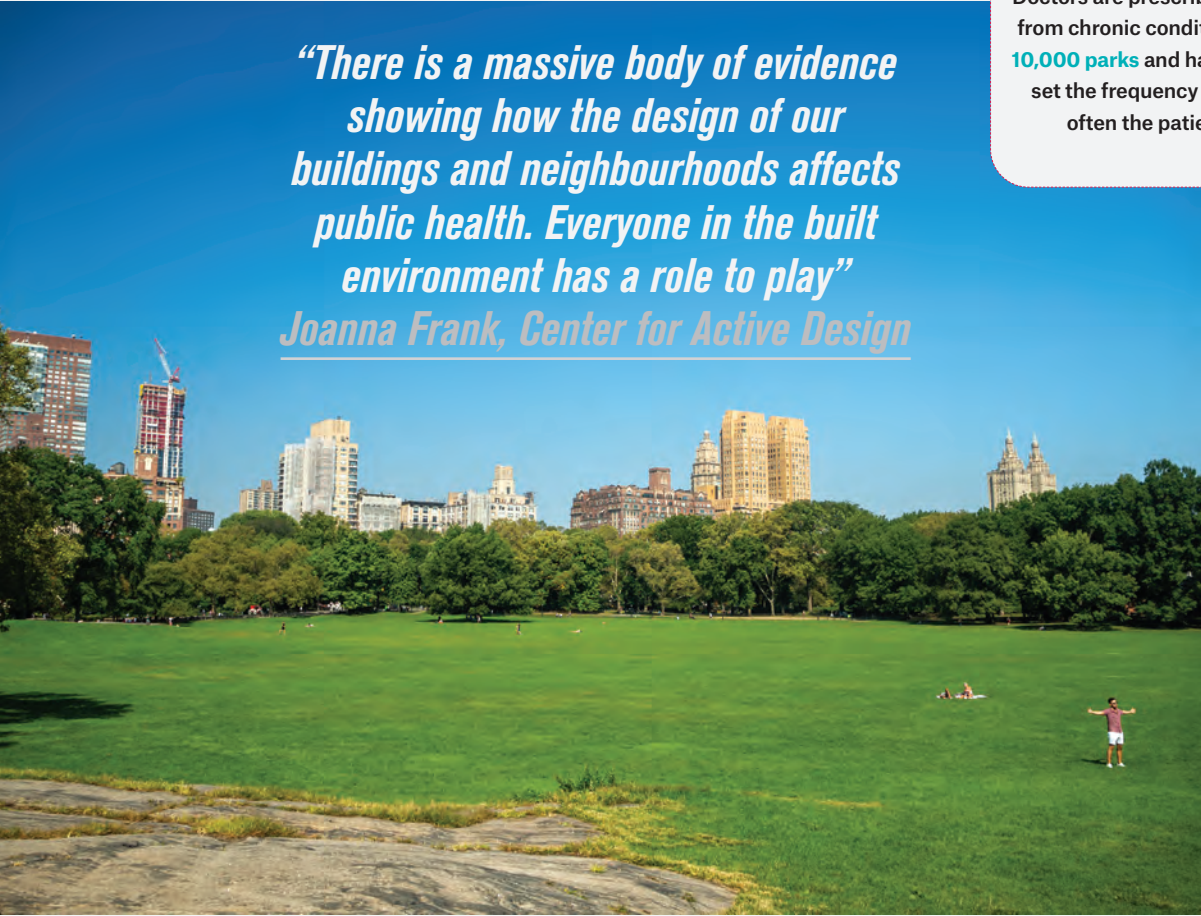
"There is a massive body of evidence showing how the design of our buildings and neighbourhoods affects public health. Everyone in the built environment has a role to play"
Joanna Frank, Center for Active Design

Photo: zaijiu/Adobe Stock

Notes [1] Spending data from *The Lancet*, Vol. 393, No. 10187, April 2019 [2,5,9,10] Population data: UNdata. World Population Prospects, 2019, based on working age of 20-69 [3] *The Lancet*, Global Burden of Disease Study 2017 [4,16,25,27] WHO [6] Health at a Glance 2019, OECD [7,15] *The Lancet* [8] WHO, 20 September 2016 [11] Global Innovation Index 2019, WIPO [12] FDA, January 2019 [13] healthweather.us [14] WHO/IHM [17] The Economic Consequences of Climate Change, OECD, 2015 [18] *The Lancet Countdown*, 2019; CarbonBrief [19] A Future That Works, MGI, 2017 [20] *The American Journal of Medicine*, Volume 131, Issue 8 [21] Accenture 2018 Consumer Survey on Digital Health [22] American Heart Association [23] Ericsson, Telia, Karolinska Institute [24] Philips, Future Health Index 2019 [26] The Mobile Economy — Sub-Saharan Africa, GSM Association, 2019 [28] CRED, Disaster Year in Review 2019 [29] The King's Fund, June 2018 [30] Global Liveability Index, Economist Intelligence Unit, 2019 [31] JLL City Momentum Index 2020 [32] World Green Building Council, October 2016 [33] parkrxamerica.org